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DEHYDRATED MASHED POTATOES--A REVIEW

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This review is concerned with the general characteristics and methods of production of dehydrated mashed potatoes and their advantages over other forms of dehydrated potato (dice, julienne strips, and riced). Patents and other available literature, up to September, 1950, have been searched for information on techniques, analytical procedures, variations in processing factors, and other factors that might be useful in controlling product quality. Storage stability of the product is briefly discussed.

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CONTENTS

Page

General Characteristics and Utilization - - - - - - - - - 2

Methods of Manufacture - - - - - - - - - - - - - - - - 3

Riced Potatoes - - - - - - - - - - - - - - - - - 3

Dehydrated Mashed Potatoes - - - - - - - - - - - - - 4

Related Products and Processes - - - - - - - - - - - - 9

Control of Quality in the Production of Dehydrated Mashed Potatoes - - - - - - 11

Analytical Procedures in Controlling Quality - - - - - - 11

Processing Operations Affecting Quality - - - - - - - - 12

Cooking - - - - - - - - - - - - - - - - - - - 12

Mashing - - - - - - - - - - - - - - - - - - - 12

Partial Drying - - - - - - - - - - - - - - - - 13

Conditioning - - - - - - - - - - - - - - - - - 13

Comminuting, Extruding, and Disintegrating - - - - - 14

Drying - - - - - - - - - - - - - - - - - - - 14

Sieving - - - - - - - - - - - - - - - - - - - 15

Other Factors Affecting Quality - - - - - - - - - - - 16

Storage Stability of Dehydrated Mashed Potatoes - - - - - - - 16

Summary - 18

Literature Cited - - - - - - - - - - - - - - - - - - 19

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Since prehistoric times potatoes have been preserved by drying. R. N. Salaman (59)[1] relates that the earliest chroniclers of the Spanish conquest of South America recorded the existence of a well established commerce in potatoes and dried potato products. The preserved products were especially valuable because of great storage stability and relative ease of transport--important factors in the communal supply system for feeding soldiers and insuring against occasional famine in the empire of the Inca.

For the same reason (storage stability and relative ease of transport), dehydrated potatoes have been used extensively in military rations in two world wars. It has been recognized, however, that products in riced, diced, or julienne-strip form are not convenient to prepare for serving. Dehydrated potato has not been successfully compressed into blocks and is somewhat bulky, particularly for military purposes. Furthermore, when prepared, dehydrated potatoes have been frequently served as lumpy mashed potatoes or badly disintegrated julienne strips or dice.

In the course of development of dehydrated potato products, attempts have been made to increase ease of preparation, reduce bulk, and improve quality. Earlier efforts in this direction resulted in production of potato shreds, a pre-cooked, extruded product. A later advancement was the preparation of dehydrated mashed potatoes. To prepare for serving, dehydrated mashed potatoes need only be mixed with hot water and/or other nutrient liquid, such as milk or reconstituted dry milk. In contrast, dried potato shreds require a short rehydration and cooking period before they can be served. Dehydrated mashed potatoes, properly prepared, have been described as the most generally acceptable of all dehydrated vegetables, having application to military and civil needs as well (40).

For military purpose the convenience and rapidity of preparation serve to make dehydrated mashed potatoes adaptable to use for mobile units and for individual rations, where necessary. For civil needs, ease in preparation makes the product a highly promising household item if it can compete favorably with fresh potatoes in quality. For restaurant use it should be of great advantage, since preparation for individual servings on short order will avoid steam-table degradation of quality.

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[1] Numbers in parentheses refer to literature cited on pages 19-23.

GENERAL CHARACTERISTICS AND UTILIZATION

In the introduction of this report we have defined dehydrated mashed potatoes as a dried potato product which can be instantaneously reconstituted by addition of hot liquid and mixing. Two general types of product meet this definition: (a) a granular product consisting of single or, at most, very small aggregates of cells and (b) a porous product consisting of larger, discrete particles, of such structure as to allow intimate contact of dried tissue with liquid on reconstitution.

Because pre-cooking is an essential step in production of dehydrated mashed potatoes, a satisfactory product can be prepared for serving in a few minutes merely by mixing with hot water in proper proportion. With this simple preparation, the texture of the product when served is apt to be much better than that of dice or julienne strips. The latter seldom mash without lumps and are likely to slough during the prolonged rehydration and cooking steps required to overcome hard center texture.

Package density has been an important factor in evaluating dehydrated foods, especially for military and emergency uses. Barker and Burton (9) reported potato granules at 0.7 to 1.0 gm. per ml. (about 5.2 to 7 lbs. per No. 10 can) as compared with potato shreds at 0.25 gm. per ml. (about 1.8 lbs. per No. 10 can). Dehydrated mashed potatoes of the porous type and larger piece size might have densities from 0.2 to 0.3. The bulk of the porous types of dehydrated mashed potatoes is a limiting factor where storage and shipping space are critical.

Rendle (54) has compared several methods of preserving potatoes, using as criteria the type of container required, the volume required for storage, the weight of stored product, and relative ease of preparation. The following table, from his article, demonstrates some of the advantages of dehydrated mashed potato granules over other preserved potato products. Porous-type dehydrated mashed potatoes would have perhaps twice the volume of dehydrated strips but would approach the granules in ease of preparation.

Table 1. Comparative Weight, Space Requirement, and Ease of Preparation of a Ton of Potatoes Preserved in Four Ways

Storage Product	Package	Space cu.ft.	Weight lbs.	Relative ease of preparation
Fresh	Sack	48	2,000	4th
Canned	No. 2½ can	94	3,720	1st
Dehydrated strips	9-lb. can	40.3	400	3rd
Mashed powder	14-lb. can	12.5	400	2nd

In general, dehydrated mashed potatoes can be used only in recipes requiring finely divided particles. However, within this limitation considerable latitude exists in the preparation of hash, soups, purees, casseroles, and other combination recipes.

METHODS OF MANUFACTURE

Riced Potatoes

Prior to the development of dehydrated mashed potatoes, improvement in rehydration characteristics of dried potatoes was sought and a number of advancements were made in precooked, dried, riced potatoes.

The concept of dried riced potatoes is not new. In 1845, Edwards (24) received a patent on a method of preserving potatoes by cooking with the peels on, removing the peels, and ricing in thin layers on hollow, steam-heated tables on which they are dried. Temperature was regulated, by control of steam flow between 160° and 100°F. The lower temperature was used as the product approached dryness. The patent claimed the art of preserving cooked or partly cooked potatoes in a finely divided and dried state.

Claiming an improved dehydrating method, Remmers (51) was granted a patent in 1918. In it he specifies the extrusion of cooked potatoes, while still hot, in thin layers on perforated sheets or screens. These are placed in a drier and dehydrated in 25 to 30 minutes at about 180°F. The result is described as a dry thread-like product which can be prepared for eating by adding an equal bulk of water and heating for a few minutes.

Before, and concurrent with, the development of dehydrated mashed potatoes, other advances were made in the production of dehydrated potato shreds.

In 1921, a patent was granted Allen (1) for another method of producing precooked dehydrated potatoes with rapid rehydration characteristics. This patent specifies (a) pre-cooking, (b) extruding as threads on trays, (c) partially drying, (d) breaking into smaller fragments, and (e) "heat sealing" during a short-duration, high-temperature, finish drying step, followed by (f) rapid cooling.

The Rogers Brothers Seed Company, a pioneer in potato dehydration for domestic consumption, became interested in potato shreds in the middle 1930's and developed a continuous ricer or extruder. This device is described as consisting of a perforated cylinder revolving on a horizontal axis with a heavy roller used to force cooked potato mash from the inside, through the perforations, on to drying trays (3,6,57).

Gano (26) and the Potato Corporation of Idaho (46) were granted patents for a process of producing potato shreds in 1940. In the specification the important relationship of ruptured vegetable cells with gluey texture of reconstituted product is recognized. To minimize cell rupture, these patents specify careful cooking of product in water made alkaline by addition of $Ca(OH)_2$ to about pH 10.0 to 10.2. The alkalinity[2] of the cooking water is considered an important factor in prevention of cell-wall rupture.

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[2] With present-day knowledge, it seems possible that in Gano's process the calcium ion in the cooking water is responsible for strengthening the cellul structure.

A method of producing potato shreds whereby yield is increased (over conventional methods) and peel is easily recovered for stock feed was reported by Stamberg and Beresford (60) in 1943. The process involves baking potatoes without peeling and peeling by hand while still hot--a process requiring little more effort than the trimming operation required with most peeling methods. No significant loss in total solids would be encountered, because the peeling wastes can be easily recovered and dried for stock feed. In addition, the disposal of liquid wastes carrying high quantities of organic material can be reduced to a minimum by the process.

Brown and Kilpatrick (13) in 1943 observed drying characteristics of riced potatoes in an engineering study directed toward new and better design and operation of dehydrators for potato shreds.

A patent was granted in 1944 to Nixon (45) specifying a process for dehydrating potatoes, fruits, and vegetables by cooking at or above 212°F. and maintaining or gradually increasing product temperature throughout cooking and subsequent dehydration to a moisture content of approximately 10 percent. The process is reported to provide a means of drying without rupturing cell walls; that is, maintenance of high temperature prevents plasmolysis and breaking of cell structure. According to specification, the product is sliced or extruded as desired, preliminary to drying.

Dehydrated Mashed Potatoes

A technique that was perhaps the first to provide an instant-cooking dehydrated mashed potato is specified in Stoddard's patent (61) of 1922. The preliminary operations are identical with those for potato shreds, as described above, but the pre-cooked product is extruded on a continuous belt and dehydrated by a counter-flowing air current at temperatures ranging up to 420°F. (215°C.). Under these conditions the product dries with an interior, tubular bore, and rehydrates rapidly. Mashed potatoes can be prepared for serving by adding butter, boiling milk, and water, and allowing only about two minutes of standing, followed by thorough beating or whipping.

In 1926 Heimerdinger (32) patented another process for dehydrating mashed potatoes. This patent specifies a spray-drying process that produces a granular material from potatoes. The product, when mixed with water and warmed, is said to have the consistency of mashed potatoes, absorbing water with greater facility and in larger portions than is possible with potato flour. The method specified consists of cooking, ricing, mixing with water, and spray drying at about 500° to 600°F. The product so made is described as non-hygroscopic, whitish granules.

Ten years later Bunimovitch and Faitelowitz (16) applied for a British patent specifying the following process. Potatoes are cooked, cut into small pieces and partially dried (50 to 60 percent weight loss) until the product can be reduced to a moist powder without rupture of cell walls, and then dried at a temperature below 185°F. (85°C.) to a moisture content of 10 to 15 percent. The product is described as easy to reconstitute to a texture similar to that of fresh mashed potatoes. Microscopic observations led to the discovery, in this work, of the importance of preventing rupture of cell walls if an acceptable product is to be obtained.

The first of a series of patents by Volpertas (63) was filed in 1937. He refers to inherent problems involved in the Buninovitch and Faitelowitz (16) patent and proposes a device and process that accomplishes the initial drying while the product is continuously stirred, crushed, disintegrated, and scraped from the walls of the drying chamber. The first stage of drying is at a temperature of about 122°F. (50°C.) and continues until about 40 to 50 percent of the original weight of product is lost by evaporation. The moist powder obtained is sifted, and drying continues to 10 to 15 percent moisture content with mixing and scraping but without crushing. At about 75 percent weight loss the temperature is raised to 176°F. (80°C.) without agglomeration of particles. As an alternative, a vacuum process is suggested for the final stage of drying.

Another British patent by Volpertas (64) was filed in 1939 on an improved process that involves adding back dry powder to freshly cooked mash in order to prepare a moist powder, which can be reduced to a dry powder by heating in a drum, with stirring, until dry. This specification also describes an alternative method whereby freshly prepared mash is partially dried by heating with stirring and dry powder is added to the partially dried mash. Vacuum drying is mentioned as an alternative but not an essential part of the procedure to achieve final drying.

In a U. S. Patent issued in 1944, Volpertas (65) introduced a further modification in which he pre-dries potatoes to one-half weight reduction, preferably, but not necessarily, under reduced pressure, by application of heat but without agitation. The mash can be dried to a moist powder with heat and agitation, without becoming gelatinous. The moist powder is subjected to a final drying, preferably under vacuum at 86°F. (30°C.). This specification includes a cooking process in the absence of water in a jacketed container. It also outlines the add-back process, utilizing previously dehydrated powder to reduce moisture content of fresh mash to achieve the partially dried state. It is recommended that oversized particles screened from the final product be added to the fresh mash.

A mashed potato powder was presented to the British War Ministry by Rivoche, of France, shortly before World War II began. King (40) states that although Rivoche presented a sample of his product, he did not divulge the method of preparation. Later the German occupation of France made it impossible for the British to communicate with Rivoche and learn more about the process. Thus 10 years elapsed before the patent was accepted. In 1948 the complete specification was accepted and in 1950 a U. S. patent (56) was issued to Rivoche for his process, specifying the cooking of potatoes, followed by cooling to 40°F. (4°C.) or lower, and reduction of moisture content below 50 percent before a final drying in hot air. With temperatures below 122°F. (50°C.) the partially dried state may be achieved by the following alternatives: (a) application of gentle heat, (b) mechanical dewatering after freezing and thawing by centrifuging or pressing between absorbent rollers with or without application of gentle heat, (c) add-back of previously dried product, (d) drying under reduced pressure with application of moderate heat, or (e) combinations of any of the above methods.

Rivoche's specifications (55,56) illustrate,diagrammatically, an apparatus for carrying out the method. With this equipment, the product is cooked, cooled, partially dried, mixed, and submitted to a final hot-air drying in a single, hermetically sealed drum in which physical conditions are controlled and changed very rapidly.

In 1940, Jones and Greer (36) applied for a British patent on a process for producing a mashed potato powder. According to the specification, cooked potatoes are broken up and partially dried in a roller drier. Moisture content is lowered to 45 to 60 percent with an optimum level at 50 to 52 percent. It is reported to be possible to comminute the partially dried potatoes in a hammermill, without undue rupture of vegetable cells, into individual cells or aggregates of cells. A hot air current is passed through the mill during the operation and the separated granules are dried during an air-borne travel after passing through the screen of the mill.

Barker (8), of the Low Temperature Research Station at Cambridge, filed a specification for a process of producing dried mashed potatoes in 1941. Cooked potato mash is partially dried to a moisture content of 40 to 60% on screens with occasional stirring or on a roller drier. The partially dried mash is then held for a period of time, depending upon the holding temperature, the moisture content, and the raw material used, until its tendency to become sticky is lost and moisture is equilibrated throughout the product. The conditioning period causes a toughening of cell walls that permits subsequent comminution without excessive cell rupture and pastiness of rehydrated product. It is suggested that the conditioning phenomena are related to retrogradation of starch and that time required is less and product better if low temperatures are used in the holding.

Barker's product is comminuted by a brush sieve technique with hot air forced through the sieve to prevent gumming of the product and fouling of the apparatus. The granules are dried on trays. Barker collaborated with Burton (10) in 1945 in filing a specification for a patent on addition of calcium ion to mashed potatoes to strengthen cell walls and lessen rupture in subsequent operations.

Proctor and Sluder in 1942 reported (48) that Hohwieler, Slüder and others in Massachusetts Institute of Technology had developed a method that produced, on a laboratory scale, potato granules of excellent quality (see also 49, 50). A low-temperature conditioning period for cooked mashed potatoes (without partial drying) is reported to be essential. Very careful extrusion into a specially constructed drier that keeps the particles suspended in a hot air stream until dry is involved in this procedure. The rather delicate extrusion operation in small batches is a limiting factor and no commercial-scale equipment was known that would produce a satisfactory product.3/

3/ Others encountered difficulty in establishing processes for the manufacture of dehydrated mashed potatoes on a commercial scale. Rendle (54) has stated that such production calls for delicate adjustment of processes and that skill in dehydrating mashed potatoes is more difficult to come by than is normally true in translation of laboratory research into plant operation.

Another author of a series of patents on potato products is Rendle (52,53), who filed in 1943 a specification for a patent on a method that is used for the first large commercial production of mashed potato powder. This process involves the reduction of moisture content to the level suitable for comminuting without undue cell rupture (45 to 60 percent) by adding previously dried potato powder as in Volpertas' (64) and Rivoche's (56) specifications. Freezing and thawing of cooked potato mash before adding powder are included as an optional step to improve reconstitution quality.

Two years later (1945) Rendle co-authored with Willets (68,69) a specification for a patent on an improvement of this method, the principal difference being freezing and thawing followed by centrifugal dewatering in place of the addition of previously dried powder to achieve a partially dried state at about 45 percent moisture content.

Fison (25) in 1943 applied for a patent on a device that provides a positive feed of wet material in comminuted form into a hot air stream. The air flow is directed upward in a zig-zag channel that allows larger particles, which dry slowly, to move more slowly through the course of drying. Dry material is collected in a cyclone-type dust collector or a porous bag separator. This drying equipment is designed specifically for use in preparing a mashed potato powder.

Using techniques developed by Rendle, Fison and others, Chivers and Sons, Ltd., of Histon, Cambridge County, England, produced 6,000 tons of potato granules for the British Armed Forces during three years of World War II (54). Commercial development of this process in the United States during the post-war period by the R. T. French Company of Rochester, New York, is the principal industrial venture in dehydrated mashed potatoes on this side of the Atlantic. Recognizing cooking, mashing, conditioning, mixing, drying, and mechanical treatment as part of prior art in the manufacture of dehydrated mashed potatoes, Bar (7) in 1943 applied for a patent in which he specified a carefully selected new combination of these known elements. His specification outlines the following process: cook, mash, condition by allowing to cool, add-back previously dried powder until the mixture becomes friable and non-sticky, and dry in a pneumatic drier.

A spray-drying technique to produce a dehydrated mashed potato was patented by Burton (19) in 1944. Recognizing the prior patent on spray-drying mashed potatoes, he concluded that earlier specifications calling for pressure cooking and pumping the product would probably cause considerable cell rupture and not produce an acceptable product. Burton's patent specifies cooking, mashing, diluting with water or nutrient liquid, sieving, and spray drying, all in a manner that does not damage tissue cells. This patent includes the addition of calcium ion to the slurry to strengthen cell walls and protect them from rupture in subsequent operations.

In 1946, Poulton and Noel, Ltd., and Bostock (47) applied for a British patent involving some of the technical principles of the Rivoche (55,56) and Willets and Rendle patents (68,69). While all specified freezing, thawing, and dewatering of potato mash by mechanical pressure (either directly or centrifugally applied), Bostock and his colleagues defined the desired freezing and thawing conditions more precisely (freeze to temperature preferably below 14°F. (-10°C.) and maintain as near 32°F. (0°C.) as possible during thawing). Furthermore, they outline, in their patent, a method whereby the peeling and trimming operations can be accomplished mechanically. Cooked, unpeeled potatoes are crushed, frozen, and broken into pieces; after thawing in water and mixing, the peel fragments and eyes are separated by sieving. The slurry containing the edible portion of potato is then dewatered mechanically and dried.

This patent (47) specifies two means of conserving the nutrients lost in mechanical dewatering. In one technique the expressed liquid is used to cook other batches of potatoes. The other method involves spray drying of the expressed liquid to a powder, which is incorporated into the dried, granular product. Alternative procedures in this patent involve mashing after freezing cooked potatoes instead of before freezing, and separation of water from the thawed mash by means of a helical screw expeller.

On a research project contracted for by the Quartermaster General of the United States Army, workers at Kansas State College (5,67) developed a dehydrated mashed potato by a freezing operation followed by partial drying in a conventional tunnel dehydrator. The partially dried material is granulated and dried in an air-duct drier in one or two passes. This work led later to improvements and the granting of a patent in 1947 to Greene et al. (30). The method (28,29,30) includes centrifugal dewatering of frozen mash for the predrying step and use of a hammer-mill type of granulator, comminuting the product directly into the hot air stream of the duct drier.

The specification includes a process of recovering most of the peeling waste normally encountered in commercial potato processing operations. After freezing and thawing of cooked, unpeeled potatoes, the product is peeled by abrasion and the peels and other tissue removed, slurried in brine solution, and separated from skins by screening. Centrifugal dewatering of the recovered tissue is followed by drying in an air duct in one or two stages. The use of a rotary drier for more gentle handling during the ultimate moisture reduction is considered.

Birdseye (12) specifies a process for the manufacture of potato granules in a patent granted in 1950. In rapid succession potatoes are diced, blanched, given a preliminary drying, cooked, dried further, frozen, thawed, mixed with dry ingredients such as skimmilk solids, extruded in several steps, and finally dried to a low moisture content. Through heat exchange steps the product is danced continuously by a vibrating conveyor belt to prevent adherence of pieces and to insure uniform treatment of all particles.

The J. R. Simplot Company of Caldwell, Idaho, large-scale producers of dehydrated potatoes during World War II, initiated pilot plant operations preliminary to commercial production of dried mashed potatoes in 1946 (4). The method involves a partial drying on screens, in a tunnel dehydrator, of potatoes that have been cooked, mashed, and riced. The partially dried material is then comminuted in a hammer-mill and dried in a two-stage air-duct drier where moisture is removed to a low level suitable for preservation of quality in storage.

Later the Simplot Company, cooperating with General Foods Corporation, has used a discovery by Kaufman et al. (38), patented in 1949, that involves thorough mixing of cooked potatoes to achieve complete homogeneity and cellular separation without substantial cell wall damage. The product is extruded through orifices in a perforated cylinder and dried rapidly without cell damage or scorching. Because of its porosity, the product can be dried in air at very high temperature. The outer surfaces of the extruded shreds dry rapidly enough under the specified conditions to prevent collapse; thus shreds of high porosity with a hollow core are formed, similar to the shreds described by Stoddard (61). The invention provides for the addition of reconstituted nonfat milk solids or other liquids during the mashing operation as a whipping aid. The product was produced in sufficient quantity to be used in extensive trial sales by General Foods Corporation but has not been marketed since the completion of the trials.

McCready et al. (43) and Harrington and Olson (31) developed in 1949 a porous dehydrated mashed potato product in cube or other form that does not require mashing, extrusion, or separation in the process. The method includes peeling, trimming, dicing, cooking, controlled freezing, and thawing. The product must be held for 0.5 to 3 hours at a temperature slightly below 32°F. (0°C.). This essential step can be accomplished by slowly reducing the temperature to several degrees below the product freezing point, by freezing rapidly and thawing very slowly, or by reducing product temperature to approximately 26°F. (-3°C.) and holding for an appropriate period of time. After proper conditioning, the product can be dehydrated by conventional means. A precaution in dehydrating is that product temperature must be below the gelation point for starch while the moisture content remains high enough to allow the starch to be resolubilized.

Related Products and Processes

Other dehydrated potato products of quick-cooking character and processing methods for their manufacture have been described in publications and patents. Several processes that are not directly pertinent to the preparation of dehydrated mashed potatoes are also discussed here, because they have been referred to in patents for pertinent processes.

An early development in potato processing was Bunyan's (17) patent in 1903 on a product claimed to be usable for food by mere addition of water. The product is now called potato flour. It is prepared by reducing cooked starchy tubers to the consistency of paste and adding boiling water to make a thin pulp. The pulp is dried in thin layers, on polished metal plates in a kiln. The dried film is broken and pulverized and, if desired, compressed into cakes or blocks. Reconstituted, it can be used in breads and bakery products but is a poor substitute for fresh mashed potatoes.

In 1905, Lankow (42) obtained a patent on freezing, thawing, pressing, and drying of potatoes. Freezing is specified to arrest vital action of protoplasm and make possible more ready removal of juice by squeezing. Freezing, not below 26.6°F. (-3°C.) over a long period of time is held to be proper, and potatoes are perforated for ease in expressing juice. Press cake, after expression, is divided to hasten dehydration. The product can be ground for meal or coarsely shredded.

The introduction of pre-cooking in Lankow's process would probably result in a product that could be prepared for serving merely by mixing with hot water. With the cooking step omitted, the product would need a short cook before it could be made into an acceptable menu item.

A process of preparing dried powder from organic material with a minimum of change in chemical properties was patented by Tival (62) in 1927. This process consists of freezing the product very rapidly by immersion in a liquefied gas and pulverizing. The pulverized material is sterilized in an oscillating electrical field or by exposure to bactericidal rays of very short wave length. The product is dried at low temperature, as under vacuum.

A patent on a potato product which is dried in a porous condition was granted Webb (66) in 1940. Non-fat milk and/or other flavoring material is added to cooked potatoes and the mixture whipped to a 60 to 100 percent overrun and dried in hot air or at reduced pressure. The product is not rehydrated but toasted to a brown color for consumption as a snack item.

The drying of potatoes under conditions of low pressure was patented by Irwin (34) in 1942. This technique gives a very porous product of high quality and quick reconstitution character, and if pre-cooked could be utilized as a quick-cooking dehydrated potato. The cost of installing equipment and maintaining a vacuum for this process is probably prohibitive for commercial use.

Also in 1942, Musher (44) received a patent specifying prolonged cooking followed by slow freezing intended to weaken connecting tissue and rupture cell walls of food products before dehydration. The tissue then takes up water more readily and reconstitution is more rapid than for conventionally dehydrated foods. While this patent indicates that potatoes are satisfactory subjects for such treatment, the over-cooking and rupturing of cell walls have been considered by other experimenters as ruinous to potato products. The release of solubilized starch from ruptured cells tends to make mashed potatoes gummy and unpalatable. Perhaps Musher's technique would be more applicable to other food products than to potatoes.

A patent, in some respects similar to Musher's, was granted Kellogg (39) in 1949. It specifies a preliminary quick freezing of pulped potato, followed by dehydration. Expansion of cellular structure expedites liberation of moisture during drying. Grinding frozen potatoes would disrupt cell structure to a degree that would preclude use as mashed potatoes after rehydration. Kellogg's specification calls for subjecting the product to drying conditions while in a chilled or frozen condition, thereby supplementing, by low temperature of product, the evaporative cooling on dehydration.

A process referred to in some publications on dried mashed potatoes is the patent of Dalsey (22). This process does not attempt to preserve the cellular structure of the product and produces a dried material to be used in batter products such as potato pancakes. A novel feature is the expression of juice from uncooked potatoes and recombining it with cooked potatoes to mix with the uncooked press cake. The entire mixture is subsequently dehydrated.

A prior patent of Brubaker (14) revealed substantially the same process applied to apples for the preparation of dry apple butter.

Another patent referred to in dehydrated mashed potato literature is that of Jansen (35). Peeled potatoes are soaked in a solution of preservative and/or salt to prevent color change and absorb a maximum of water. The product is then macerated to a finely divided state and dried, to be subsequently used in potato pancakes or other recipes calling for fresh potatoes.

CONTROL OF QUALITY IN THE PRODUCTION OF DEHYDRATED MASHED POTATOES

Analytical Procedures in Controlling Quality

In the development of dehydrated mashed potatoes, objective and semiobjective methods of analysis have been developed, correlated with acceptability of reconstituted product, and used to help control operations. The relationship of cell-wall rupture to stickiness in reconstituted product is almost universally observed. Microscopic examination has been used in many instances to count or estimate the number of broken cells, and the values obtained have been used as a measure of texture quality of rehydrated mashed potatoes.

Bunimovitch and Faitelowitz (16) related quality of product to cell-wall damage by microscopic observation of cell-wall rupture, and utilized these observations in the original development of their process. Greene et al. (28,29,30) counted ruptured cells in a microscopic field. They found that 20 percent of ruptured cells gives a very pasty product; 10-12 percent, average; and below 6 percent, superior. Workers at Massachusetts Institute of Technology (48,49,50) found a microscopic examination for broken cells a suitable method for control of product and could estimate, from the condition of the potato mash at various stages of the process, what the acceptability of subsequently reconstituted powder would be.

Harrington and Olson (31) have used microscopic examination to observe broken tissue cells and also to observe angulation or shrinkage of cells. Uniform angution indicated that the freezing step in their process accomplishes the desired result. When cell shrinkage is uniform, the product maintains a porous texture through subsequent dehydration.

Barker et al. (9,11) used as a quality test the viscosity of supernatant liquid obtained in centrifuging a mixture of water and potato mash, or dried potato powder. Free solubilized starch from broken cells was responsible for increased viscosity. This method was found suitable for control during the process. The group at Massachusetts Institute of Technology (48,49,50) also used this viscosity measurement but found it less valuable for control work than microscopic examination; the latter method is not subject to physical conditions.

A method using iodine color to estimate free soluble starch from filtered extracts of mashed potatoes was developed at Massachusetts Institute of Technology (48,49,50) but was also found inferior to microscopic examination.

Processing Operations Affecting Quality

In reviewing the findings on the effect of processing methods on quality of product, we have found it advisable to consider unit operations apart from each other even though a certain amount of repetion is necessary.

Cooking: To prevent rupture of cell walls during cooking, avoidance of vigorous boiling or steaming under pressure is recommended (11,18,19). Overcooking has been found to weaken cell walls, producing an inferior product (19), and 220°F. (105°C.) is considered a maximum cooking temperature with hot air or steam (55,56).

Techniques of cooking that partially dehydrate the product by heating in the absence of water and drawing off steam during the process have been specified (55,65). In one method (65) a covered jacketed kettle is heated with circulating boiling water. Slight pressure is allowed and the product is stirred only to obtain uniformity of heating. Acidification of cooking water has been found to improve color of product (18).

In a process involving mechanical dewatering of frozen and thawed potato mash, a cook in the liquid expressed from previous batches of product has been specified to reduce loss of nutrients and improve yield of dry material (47).

Mashing: Potatoes should be mashed while still hot from cooking; otherwise many cells will be damaged and a poor product will result (9). Improper mashing will adversely affect quality, and if potatoes are not adequately mixed, cell separation will be incomplete and the product will not be homogeneous. Under these conditions drying will be uneven (38). Addition of reconstituted dry milk or other liquid improves whipping characteristics (38). If potatoes are undercooked, excessive cell damage will occur in mashing (18).

The mashing of potatoes can be accomplished by a whipping or mixing technique (38), by crushing between rollers (47), or by forcing cooked potatoes through a perforated plate (47) or the perforated walls of a rigid container (32).

Mashing potatoes by a combination of mixing, crushing, disintegrating, and stirring while the product is being dehydrated is a method that has been described as a means of obtaining uniform drying and a homogeneous product (63). After reduction of moisture content of cooked potatoes to about 50 percent, mashing or mixing can be increased in intensity to achieve the maximum disintegration. Before that reduction, however, and during conditioning and other pre-drying operations, moderate mixing has been advised (55,56). In a patent on a method involving conditioning of product by freezing, it is stated that mashing can be done before or after the freezing step (47).

Partial Drying: Even in early patents on dehydrating of mashed potatoes it is recognized that reduction of moisture content to about 50 percent makes possible the disintegration of cooked potato tissue without harmful cell rupture. Partial drying by conventional dehydrating procedures with cooked product in dice form is suggested (16), and also thorough mixing of cooked potato mash during drying (8,55,56,63). Another technique by which the partially dry condition is obtained is the addition of an appropriate amount of previously dried powder (7,52,53,54,55,56,64). Improvement in quality by cooling or freezing before addition of dry powder is claimed for some processes (7,52,53,54).

Use of a roller drier for partial dehydration has been proposed and limits of 45 to 55 percent moisture content have been set for production of satisfactory product. Over- or underdrying are held likely to be responsible for poor quality of product, and temperatures in excess of 266°F. (130°C.) are to be avoided, to prevent cell damage (36,37).

Another means of reducing moisture content of cooked potatoes is the application of pressure after the product has been frozen and thawed (28,29,30,47,55,56,68). Expression of liquid from potato tissue by application of centrifugal or direct pressure is suitable and one of the patents also specifies use of a helical screw expeller (47).

Difference of opinion exists on rate of freezing. Willets and Rendle (68) say that quick freezing causes less damage than slow freezing. Greene et al. (28,29), on the other hand, report no effect on cells from slow freezing and state that quick freezing adversely affects ability of tissue to release water; further they report that too rapid thawing renders cells more susceptible to rupture. According to their theory, the toughening of cell walls during freezing is not completed as the product reaches the frozen state, but is a function of the duration of holding in the frozen state. According to Greene et al., dewatering of thawed mashed potatoes removes certain nutrients and soluble solids and reduces yield, but the net effect can be an improvement, because some components related to quality degradation in process and storage are thus removed (28,29).

Conditioning: A conditioning period can be used to render cooked mashed potatoes friable and less sticky, so that they can be extruded or separated without excessive cell damage (7,8,9,11,48,49,50,55,56,65). Temperature of conditioning is important and, if low enough, partial drying can be eliminated. While partial drying is not a necessary step, it makes possible significantly shorter conditioning periods (8,9,11). For partially dried mash, the conditioning period servesto equilibrate moisture throughout the product as well as to allow cell walls to toughen.

Freezing and thawing of potato mash make dehydration possible without shrinking and caking of product (28,29,30,47,52,53,55,56). Slow freezing and slow thawing are recommended to accomplish maximum resistance to rupture of cell walls. Use of warm water to control thawing rate has been specified (47). With carefully selected raw material and with freezing and thawing rates carefully controlled, it has been possible to dehydrate potatoes in discrete pieces with a porous structure that readily absorbs water on rehydration (31,43). By this means it is possible to eliminate mashing and comminuting steps.

Application of calcium ion after cell separation (as by mashing) and before subsequent drying is specified to render cell walls less susceptible to rupture in mechanical handling of product (9,10,19). In addition to strengthening the cell walls, calcium ion appears to lighten product color. In concentrations recommended (less than 0.2 percent of calcium chloride to weight of product) no detectable flavor is introduced and no effect on storage stability has been observed.

The conditioning required is dependent, in part, on the raw material used. Tubers of waxy texture in general take longer periods of conditioning and in extreme cases a satisfactory product cannot be produced (9,48,49,50). Prolonged conditioning periods should be avoided; otherwise vitamin C loss and even microbial spoilage may occur (11).

Comminuting, Extruding, or Disintegrating: Partially dried, cooked potato dice can be divided to form a moist powder by grating or crushing (12,16). A method proposed to obtain a granular dried product is to mix or stir cooked potato mash while drying to prevent agglomeration of separated particles

Hammer-mill-type disintegrators have been suggested to separate partially dried potato mash to granular particles (28,29,30,36,37,65). One patent specification calls for passage of hot air through the mill to prevent fouling of the screen (36,37).

A brush sieve has been devised that is equipped with a means of directing a hot-air stream to prevent accumulation on the screen of moist fiber and broken cells (8,9). An extruder that exerts a combined pressing and rubbing action to force conditioned (but not partially dried) potato mash through a perforated cone has proved successful for small batches only (48,49,50).

Rubbing the partially dried potato mash through a screen has been specified (47,55,56). Rendle, however, warned against rubbing through a screen lest the cell walls be unduly damaged and specified a vibrating screen to effect the separation of moist, partially dried potato mash (52,53). Mechanisms which expel the moist product in particles into a venturi-type tube for drying have been considered (25). In extruding mashed potatoes through perforations, the minimum size of holes is determined by possible cell damage from orifices of too small dimensions (38).

Drying: Spray drying has been considered as a means of dehydrating cooked potato mash (9,11,32). A slurry of 14 to 15 percent total solids has been found suitable in consistency for spraying (9,11). Spray drying is also specified to recover soluble solids from liquid expressed from frozen and thawed cooked potatoes (47).

For dehydration in retorts or on trays, mechanical agitation or occasional stirring is reported to be necessary, to obtain a uniformly dehydrated product (47,55,56,63,64,65). In our own studies, however, we found it possible to dry a friable, moist powder (obtained from potato mash by mechanical dewatering after freezing and thawing, or by add-back of previously dried product) on lightly loaded trays without agitation of product.

Regarding the allowable maximum temperature of drying, some difference of opinion exists. Buninovitch and Faitelowitz (16) specify a dehydration temperature of 185°F. (85°C.) or lower for mashed potatoes. Volpertas (63,64,65) indicates 122°F. (50°C.) as a maximum drying temperature until the product loses about 75 percent of its weight by evaporation, after which the temperature can be increased to about 175°F. (80°C.) without agglomeration of particles. Too high temperature in the latter stages of dehydration will cause discoloration. Rivoche (56) also indicates that 122°F. (50°C.)is a maximum drying temperature in the early stages. After reduction of moisture content to 50 percent, he specifies temperatures of 212°F. to 230°F. (100° to 110°C.) as suitable for finish drying. Harrington and Olson (31) have found 120°-130°F. (55°-60°C.), the gelation point of starch, to be an appropriate maximum product temperature during dehydration.

In flash drying of potato granules during air-borne travel, higher temperatures appear to be feasible. Jones and Greer (36,37) specify 302°F. (150°C.) and Rendle (52,53,54), 260°F. (127°C.).

A number of driers have been developed that suspend particles of potato mash in air until they dry. One such drier holds the drying granules suspended in an upward-directed, vertical air stream. Moist heavier particles are suspended at lower levels, nearer the heat source, and a uniformly dry product results (48,49,50). Another development involves blowing the divided particles through a vertical, zigzag column through which larger and heavier particles move more slowly in the upward-directed air-flow (25). Other devices suggested are pneumatic (7,47), tray (31,47), belt (47), and tower (47) driers. Air suspension driers for food products other than quick-rehydrating mashed potatoes have been described (3a, 45a).

A duct drier has been developed in which a granular product can be dried in one or two stages (28,29,30). In this type of drier impact and abrasion can cause cell damage in the final drying stages (below 20 percent moisture content). Rotary kiln-type driers for a final stage of drying have been suggested as a means of final moisture reduction with minimum cell damage (28,29,30).

In producing a porous dried product from extruded mashed potatoes, rapid drying conditions are used, which firm the outside portion of the shreds and prevent collapse, producing a product that rehydrates rapidly (38,61). Drying foods under reduced pressure conditions has been patented (34), and vacuum drying has been specified in several other patents as feasible but not an essential (16,55,56,63,64,65).

Sieving: Sieving has been used as a method of controlling quality of dehydrated mashed potatoes. The fraction passing a 200-mesh screen gives a pasty product on reconstitution (18), and sieving has been suggested as an adequate means of grading the product (47). In add-back processes, oversized particles, screened from dry product, are mixed with wet mashed potatoes to achieve partial drying (52,53,65).

Other Factors Affecting Quality

Suitability of raw material is important in quality of dehydrated mashed potatoes. It has not been demonstrated that mashed potatoes made from dehydrated products can be of better quality than that made from original raw tuber stock. Barker et al. (11), Barker and Burton (9), Burton (18), Proctor et al. (48,49,50), and Rendle (54) state that the non-waxy type of potatoes are required for dehydrated mashed potatoes of acceptable texture. Burton (18) states that tuber stock should be of such character that it will not darken on cooking.

Burton (18) found that pH can affect color of product and that acidity of reconstituted mashed potatoes should not greatly exceed that of the fresh mash (pH 5.7 to 6.0). The pH can be adjusted by softening or otherwise reducing the pH of water used in cooking and reconstitution.

Barker et al. (11) and Greene et al. (28,29,30) indicate that preparation of dehydrated mashed potatoes causes greater loss of vitamin C than other dehydration processes. This loss may be offset, however, by retention of virtually all remaining vitamin C through very rapid reconstitution. The net result might favor dehydrated mashed potatoes over other dried potato products. Jones and Greer (36,37), on the other hand, state that the rapid drying rates possible in granule dehydration effectively retain more vitamin C than other dehydration procedures.

The possibility of metallic contamination of product from the processing equipment has been considered by Burton (18,19) and Rendle (52,53). Avoidance of copper, brass, and iron is recommended.

Barker et al. (11) indicate that a good product can be made unacceptable by reconstitution in boiling water, and that cell rupture can be avoided by use of slightly lower than boiling temperature in rehydrating.

In an attempt to increase product density and convenience of handling, Ingram and de Rousset-Hall (33) made compressed and molded blocks of dehydrated mashed potatoes by addition of fat. More fat was required for molding than for compressing, and 30 percent fat was found to be a maximum level above which palatability was adversely affected. Specific gravity could be increased about 25 percent, but oxidation of fat became a limiting factor in storage. High temperatures in storage were not feasible, but at 68°F. (20°C.), product was stored for sixteen weeks with no significant flavor change. In their studies on compression, Ingram and de Rousset-Hall (33) found that up to 20 percent of milk powder could be added without significant change in palatability.

Storage Stability of Dehydrated Mashed Potatoes

Storage stability of dehydrated potato products varies with many factors, including raw material, conditions of process, packaging, and conditions of storage. Many of these factors have been evaluated for dehydrated potatoes in general (58). The Low Temperature Research Station at Cambridge, England, has been the principal contributor to knowledge of storage deterioration of dehydrated mashed potatoes. The work of Burton (20,21), Barker et al. (11), and Barker and Burton (9) is briefly summarized below.

A gradual loss of flavor and two major deteriorative processes were found in stored dehydrated mashed potatoes. A brown color and charred flavor develop and an "off" flavor of different character is encountered. Both processes are accelerated by increased storage temperatures, with the former predominating and masking the latter at high temperatures. At moderate temperature a decrease in rate of "off" flavor development has been found to be correlated with increase in moisture content above 5.5 percent. This relationship has not been observed with moisture content below 5.5 percent. However, increase in moisture content promotes an increase in the rate of browning.

Certain reactions during storage have been observed: (a) anaerobic development of brown color with the evolution of carbon dioxide, (b) absorption of oxygen with the evolution of carbon dioxide, and (c) absorption of oxygen unaccompanied by evolution of carbon dioxide but resulting in an "off" flavor. These observations plus studies of composition, storage conditions, and flavor evaluation have led to the conclusions presented below:

First, the "off" flavor development is held to be due to oxidative rancidity of fat (0.1 to 0.9 percent is found in dry potato powder). Evidence favoring this concept is: (a) oxygen is absorbed with negligible evolution of carbon dioxide, (b) storage in inert atmosphere retards the development of "off" flavor, (c) "off" flavor is retarded by increased moisture content (similar to high-moisture-content protection against rancidity in wheat flour and dried milk), (d) deterioration is accelerated by exposure of product to light, and (e) the odor and flavor are typical of rancid fat.

Second, the browning reaction in dried mashed potatoes is probably a complicated chemical mechanism. A loss in total sugar was observed with browning but there was no obvious correlation of amount of loss with degree of browning. Correlation with loss of glucose was more readily apparent. Initial hexose content determines rate of browning in early stages; the intensity of color reaches a maximum determined by total amount of sugar present. Possibly caramelization of glucose is more important in browning at the early stages, with Maillard reaction playing a part in later development of more intense browning.

Browning has been found to be related to pH and buffering power of water extracts of dried potato products. Bleaching occurs when product is exposed to light. Several means of controlling storage deterioration have been studied. Reduced temperature is particularly effective. Packing in nitrogen atmosphere retards "off" flavor development, but small amounts of oxygen render such treatment ineffective. Packing in inert atmosphere is an important factor in retention of vitamin C.

Another control method is adjustment of moisture content to minimize deterioration. Over a range of moisture contents (above 5.5 percent), high levels retard "off" flavor but increase browning tendency and loss of vitamin C. Above 12.2 percent moisture, a mold taint has been observed.

The other principle proposed to retard deterioration is addition of sulfite. Sulfite reduces processing losses (but not storage losses) of vitamin C, improves initial color, and retards "off" flavor of dehydrated mashed potatoes of los moisture content during storage. It addition it was observed that addition of 10 percent of whole milk powder doubled storage life of dehydrated mashed potatoes at 3 percent moisture content. It is possible, however, that developing off flavor was masked by the less unpleasant cheese-like flavor developed in the early stages of deterioration of the dried milk. Without these controls, dehydrated mashed potatoes of 4 to 6 percent moisture content have been stored at 59°F. (15°C.) for twelve months with no significant flavor change. With higher moisture contents or higher storage temperature, the storage life was appreciably shorter. With sulfite, low moisture content, and inert-gas packing, a storage life of two years in temperate climates can be expected.

SUMMARY

A difficulty encountered in the production of dehydrated mashed potatoes has been excessive cell rupture. When tissue cells are damaged, solubilized starch is released; if the amount is large the reconstituted product is pasty instead of fluffy and appetizing. To avoid this condition, several basic techniques have been developed that allow handling without appreciable damage to the structure of cells.

The earliest patent issued on a process for drying mashed potatoes in a form that could be instantaneously reconstituted, provides for rapid dehydration of pre-cooked potato shreds. With proper control of drying conditions a porous product of rapid rehydration character is reported to be produced instead of a vitreous product, as with conventional dehydrating methods.

Another early development involved separating cooked potatoes into individual cells or small aggregates of cells by mixing with water. The homogeneous slurry so prepared was intended to be spray dried.

A very general technique for producing dehydrated mashed potatoes is utilization of effect of partial dehydration of cooked potato tissue. At a moisture content of approximately 50 percent, starch gel strength and cell-wall toughness reach a maximum. Under these conditions cooked potato dice or mash can be reduced to a moist, friable powder without undue cell wall rupture and without stickiness. To reach this state, cooked potatoes are (a) pre-dried on trays or roller driers, (b) mixed with an appropriate amount of previously dried powder, or (c) dewatered by direct or centrifugal pressure after cooking, freezing, and thawing.

With other methods it has been found possible to condition the cooked potatoes so that stickiness decreases and the mash can be divided into small particles or individual cells without excessive cell rupture. A holding period is used, the duration of which is dependent upon the temperature, the raw material used, its moisture content, and possibly other factors. Conditioning at temperatures below freezing, if properly controlled, produces a product of superior texture and rapid dehydration character. Calcium salts are recommended in some instances to toughen cell walls so that they are not ruptured easily.

If cooked potatoes are in the proper state (achieved by lowering the moisture content to an optimum level and/or conditioning by suitable holding at proper temperature), disintegration into a granular product can be accomplished with a hammer-mill type of comminutor. On the other hand, some of the methods that have been developed depend upon very delicate extrusion techniques that seriously hamper expansion from laboratory to commercial-scale operations.

The techniques described involve several drying methods. The flash drying of comminuted particles while air borne is common to a number of processes reported. Spray driers, duct driers, pneumatic driers, and air-suspension driers have been investigated and specified by various research groups. Retorts that allow continuous mixing during the drying operation have been designed, and other patents specify standard-type cabinet or tunnel dehydrators with and without occasional mixing of the product.

Very few of the methods discussed in this report have been applied in commercial production. Notable exceptions are the Rendle process (52,53), which is used in England and the United States to make product for retail sale; the Kaufman _et al_. method (38), which also has been developed on a commercial scale in the United States; and a process based on the Rivoche specification (55), which is used in England and being established in the United States at the present time.

Literature Cited

1. Allen, A. E. Process of Dehydrating Potatoes. U. S. Patent 1,377,172 (May 10, 1921).

2. Anon. French's Instant Potato. Food in Canada 9(5):31 (May, 1949).

3. Anon. How Potato Shreds are Made. Food Indus. 15(3):47-9 (March, 1943).

3a. Anon. Meat Dehydration. U.S. Dept. Agr. Circ. 706 (Aug., 1944).

4. Anon. Simplot Shifts Production Set-up. Food Packer 27(7):39-40 (1946).

5. Anon. Interim Report on Potatoes, White Granules, Dehydrated. Office Quartermaster General. 8 pp. Processed. (Undated).

6. Anon. Potato Shreds. Rogers Bros. Pioneered Development of Dehydrated Potato Shreds. West. Canner and Packer 35(2):37, 39, 41 (Feb., 1943).

7. Bar, P. J. Dehydrated Potato Product and Method of Making Same. British Patent 566,498 (Feb. 10, 1943).

8. Barker, J. Improved Process for Producing Starchy Vegetable Products in Dry Powdered Form. British Patent 542,125 (March 15, 1941).

9. Barker, J., and Burton, W. G. Mashed Potato Powder. I. General Characteristics and the "Brush-sieve" Method of Preparation. Jour. Soc. Chem. Ind. 63:169-172 (1944).

10. Barker, J., and Burton, W. G. Improvements in or Relating to the Processing of Potatoes. British Patent 567,912 (March 28, 1945).

11. Barker, J., Burton, W. G., and Gane, R. Mashed Potato Powder. I. Properties and Methods of Production. Great Britain Dept. of Sci. and Ind. Res. and Ministry of Food. Dehydration; United Kingdom Prog. Rept., Sec. VI, part 6. 10 pp. (Jan., 1943).

12. Birdseye, C. Dehydration of Food Products. U. S. Patent No. 2,523,552 (Sept. 26, 1950).

13. Brown, A. H., and Kilpatrick, P. W. Drying Characteristics of Vegetables--Riced Potatoes. Trans. Am. Soc. Mech. Eng. 65:837-42 (Nov., 1943).

14. Brubaker, P. S. Dry Apple Butter. U.S. Patent 2,115,191 (Apr., 26, 1938).

15. Buchanan, A. E., Jr. Sprayed Spuds. Sci. American 146:168 (March, 1932).

16. Bunimovitch, M., and Faitelowitz, A. An Improved Method of Reducing Potatoes and Other Starch-Containing Vegetables to the Form of a Dry Powder. British Patent 457,088 (June 10, 1936).

17. Bunyan, F. Food Product and Process of Preparing Same. U.S. Patent 727,585 (May 12, 1903).

18. Burton, W. G. Mashed-Potato Powder. II. Spray-Drying Method. Jour. Soc. Chem. Ind. 63:213-15 (1944).

19. Burton, W. G. Improvements in or Relating to the Production of Dried Potato. British Patent 566,828 (March 16, 1944).

20. Burton, W. G. Mashed Potato Powder. III. The High-Temperature Browning of Mashed Potato Powder. Jour. Soc. Chem. Ind. 64:215-8 (1945).

21. Burton, W. G. Mashed-Potato Powder. IV. Deterioration Due to Oxidative Changes. Jour. Soc. Chem. Ind. 68:149 (1949).

22. Dalsey, D. Food Product. U.S. Patent 2,120,777 (June 14, 1938).

23. Durant, O. R. Process for Simultaneously Peeling and Slicing Potatoes. U.S. Patent 1,151,674 (Aug., 31, 1915).

24. Edwards, Charles S. Improvement in Preserving Potatoes. U.S. Patent 4,337 (Dec. 31, 1845).

25. Fison, F. J. Improvements in or Relating to a Method of and a Means for Drying Powdered or Other More or Less Finely Divided Material. British Patent 566,170 (June 11, 1943).

26. Gano, O. Treatment of Potatoes to Produce Dried Mashed Potatoes. U.S. Patent 2,190,063 (Feb. 13, 1940).

27. Greenbank, G. R., and Holm, G. E. Some Factors Concerned in the Autoxidation of Fats. Indus. and Engin. Chem. 16:598-601 (1924).

28. Greene, J. W., Marburger, G. C., and Rohrman, F. A. Instant Mashed Potatoes from Dehydrated Granules. Food Indus. 19:1622-25, 1749-51 (Dec., 1947).

29. Greene, J. W., Rohrman, F. A., Marburger, G. C., Honstead, W. H., Messenheimer, A. E., and Olson, B. E. Development of a Potato Granule Process. Chem. Eng. Prog. 44(7):547 (July, 1948).

30. Greene, J. W., Conrad, R. M., and Rohrman, F. A. Dehydrating Process for Starchy Vegetables, Fruits, and the Like. U.S. Patent 2,490,431 (Dec. 6, 1949).

31. Harrington, W. O., and Olson, R. L. Quick Cooking Dehydrated Potatoes (manuscript).

32. Heimerdinger, H. M. Food Product. U.S. Patent 1,571,945 (Feb. 9, 1926).

33. Ingram, M., and deRousset-Hall, O. Dried Mashed Potato Blocks. Food Mfr. 24(7):297-300 (July, 1949).

34. Irwin, J. C. Dehydrating Process. U.S. Patent 2,292,447 (Aug. 11, 1942).

35. Jansen, E. G. Method of Preparing a Food Product. U.S. Patent 2,176,347 (Oct. 17, 1939).

36. Jones, C. R., and Greer, E. N. Improvements in or Relating to the Reduction of Potatoes and Other Starch-Containing Vegetables to Dry Powder. British Patent 537,669 (Jan. 19, 1940).

37. Jones, C. R., and Greer, E. N. Mashed Potato Powder. II. Hammer-Mill Process. Great Britain Dept. of Sci. and Ind. Res. and Ministry of Food. Dehydration; United Kingdom Prog. Rept., Sec. VI, part 6. (II) (1943).

38. Kaufman, C. W., Burgess, N. M., and Hollis, Frank, Jr. Process of Preparing Dehydrated Mashed Potatoes. U.S. Patent 2,481,122 (Sept. 6, 1949).

39. Kellogg, J. L. Method of Dehydrating Food Products. U.S. Patent 2,467,318 (Apr., 12, 1949).

40. King, J. Scientific Problems in Feeding a Modern Army in the Field. Chem. and Ind. 47:739-43 (Nov. 20, 1948).

41. King, R. W. Evaporated Vegetable Product. U.S. Patent 1,259,635 (March 19, 1918).

42. Lankow, F. Improvements in the Preservation of Potatoes. British Patent 1,048 (Oct. 12, 1905).

43. McCready, R. M., Olson, R. L., and Harrington, W. O. Process of Preparing Dehydrated Potato Food Products (patent applied for).

44. Musher, A. Dehydrated Prefrozen Food Product. U.S. Patent 2,278,472 (April 7, 1942).

45. Nixon, E. L. Preservation of Potatoes, Fruit, and Vegetables. U.S. Patent 2,339,028 (Jan. 11, 1944).

45a. Peebles, D. D. Dried Food Products from Carrots, Beets, Turnips, and the Like. U.S. Patent 2,005,238 (June 18, 1935).

46. Potato Corporation of Idaho. Treatment of Potatoes to Produce Dried Mashed Potato. British Patent 526,474 (Sept. 19, 1940).

47. Poulton and Noel, Ltd., and Bostock. B. R. Improvements in or Relating to the Dehydration of Potatoes. British Patent 589,830 (Jan. 15, 1946).

48. Proctor, B. E., and Sluder, J. C. Dehydration of Precooked White Potatoes in Granular Form. Research Reports on Quartermaster Contract Projects, Massachusetts Institute of Technology. pp. 140-151 (July 1, 1942 to June 30, 1943).

49. Proctor, B. E.,and Sluder, J. C. Dehydration of Precooked White Potatoes in Granular Form. Research Reports on Quartermaster Contract Projects, Massachusetts Institute of Technology (July 1, 1943 to June 30, 1944). pp. 227-43.

50. Campbell, W. L., Proctor, B. E., and Sluder, J. C. Dehydration of Precooked White Potatoes in Granular Form. Research Reports on Quartermaster Contract Projects, Massachusetts Institute of Technology. (July 1,1944 to June 30, 1945, pp. 248-73; July 1, 1945 to Oct. 31, 1945, pp. 20-21).

51. Remmers, B. Method of Preparing Precooked Food Products. U.S. Patent 1,258,047 (March 5, 1918).

52. Rendle, T. Improvements in and Relating to the Preparation of Cooked Starchy Vegetables in Powder Form. British Patent 566,167 (Feb. 8, 1943).

53. Rendle, T. Preparation of Cooked Starchy Vegetables in Powder Form. U. S. Patent 2,381,838 (Aug. 7, 1945).

54. Rendle, T. The Preservation of Potatoes for Human Consumption. Chem. and Ind. No. 45, 354-9 (1945).

55. Rivoche, E. J. Improvements in and Relating to the Drying of Vegetables. British Patent 601,151 (Sept. 16, 1939). (Complete Specification accepted April 28, 1948.)

56. Rivoche, E. J. Drying of Starchy Foodstuffs. U.S. Patent 2,520,891 (Aug. 29, 1950).

57. Rose, R. K. Unpublished Communication.

58. Ross, A. F. Deterioration of Processed Potatoes. Advances in Food Research I:257-90 (1948).

59. Salaman, R. N. The History and Social Influence of the Potato. Cambridge, England, University Press. 685 pp. (1949).

60. Stamberg, O. E., and Beresford, H. Potatoes Baked, Then Dehydrated to Avoid Loss of Product. Food Indus. 15(9):78-9 (Sept., 1943).

61. Stoddard, E. S. Precooked Food. U.S. Patent 1,402,108 (Jan. 3, 1922).

62. Tival, H.L.P. Means of Preparing Products of Organic Origin. U.S. Patent 1,630,985 (May 31, 1927).

63. Volpertas, Z. Improvement in Process and Device for Reducing Vegetables Containing Starch to Dry Powder. British Patent 496,423 (Oct. 14, 1937).

64. Volpertas, Z. Process for Reducing Vegetables Containing Starch to a Dry Powder. British Patent 525,043 (Feb. 13, 1939).

65. Volpertas, Z. Art of Dried Starch Bearing Food. U.S. Patent 2,352,670 (July 4, 1944).

66. Webb, B. H. Food Product. U.S. Patent 2,185,451 (Jan. 2, 1940).

67. Werts, Merrill. They've Lost Their Eyes. The Kansas Agricultural Student 23(3):11 (Mar., 1947).

68. Willetts, A. K., and Rendle, T. Improvements in and Relating to the Production of Mashed Potato Powder. British Patent 589,876 (Nov. 7,1945).

69. Willetts, A. K., and Rendle, T. Production of Mashed Potato Powder. U.S. Patent 2,439,119 (Apr., 6, 1948.